Chorus, Sferics, Tweaks, and Whistlers

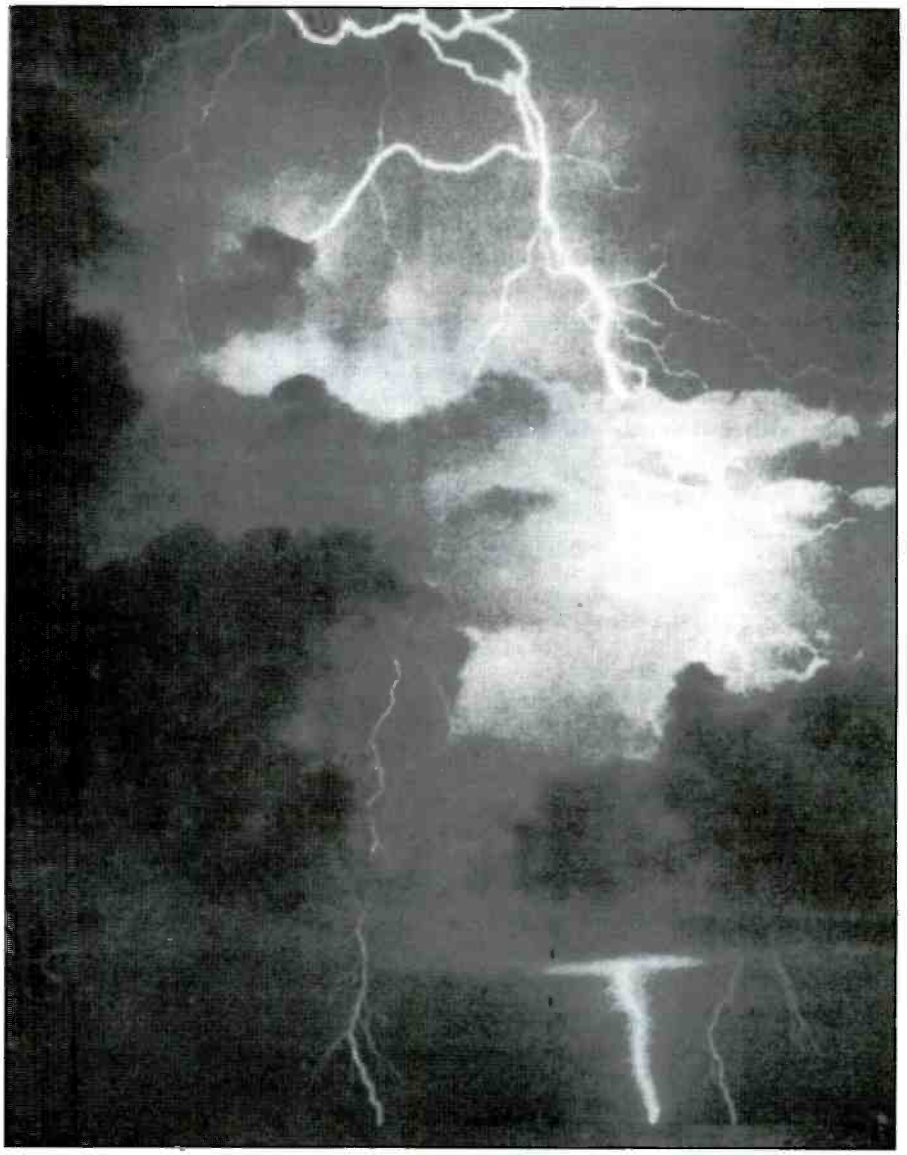
Strange VLF Natural Radio Phenomena Continues to Fascinate

BY STEVE McGREEVY, N6NKS

Welcome to the realm of very-low-frequency (VLF) "Natural Radio!" A rapidly growing group of people are interested in monitoring the Earth's huge variety of naturally-occurring VLF phenomena, whether for casual curiosity and aesthetic appeal or for serious research purposes. Naturally occurring VLF radio emissions of Earth will occur in the 0.2 to 11 kHz (audio frequency) VLF electromagnetic spectrum.

Planet Earth—along with several other planets in the Solar System including Venus, Jupiter, Saturn, Uranus, and Neptune—produces a variety of naturally occurring radio emissions at the lowest end of the radio spectrum. These emissions are primarily in the form of electromagnetic (radio) impulses generated by the planets' ongoing lightning storms, and from the Sun's solar wind interacting with the magnetic envelope surrounding the Earth, call the "Magnetosphere." These VLF naturally-occurring radio emissions are the subjects of ongoing scientific research by both amateur and professional groups, and are being monitored both on the ground by specialized VLF receivers such as the WR-3 and by unmanned space probes and satellites.

It is at these lowest frequencies of the radio spectrum (0.2 to 10 kHz) in which no man-made signals are assigned, that planet Earth's own mysterious radio emissions have been happening for eons. These fascinating "sounds" are "primal radio"—indifferent to the affairs of humankind—and insight into the causes of these ancient phenomena has only begun to be unraveled in the past four decades.



A lightning flash originates a burst of VLF radio energy that can be heard thousands of miles away.

Lightning Storm Atmospherics and Tweaks—Not Just Static

Besides 50 or 60 kHz (and harmonics) alternating-current power line "hum" from electric-utility power grids, the most noticeable sounds are going to be the snap, crackle, and pop of lightning-stroke electromagnetic impulses (called "atmospherics" and "sferics" for short) from lightning storms within a couple thousand miles of the receiver—the more powerful the lightning stroke or the closer it is to the VLF receiver's location, the louder the pops and crashes of sferics will sound in the headphones. Several million lightning strokes occur daily from an estimated 2000 storms worldwide, and the Earth is struck 100 times a second by lightning. At times the receiver's output is a cacophony of crackling and popping sferics from lightning strokes originating in storms near and far.

These huge sparks of lightning strokes are powerful sources of electromagnetic

(radio) emission throughout the radio-frequency spectrum—from the very lowest of radio frequencies up to the microwave frequency ranges and the visible light spectrum. However, most of the emitted electromagnetic energy from lightning is in the very lowest part of the radio spectrum, from 0.1 to 10 kHz. The radio pulses produced by lightning strokes travel enormous distances at these very-low radio frequencies, following the surface of the Earth as "ground waves." It is interesting how generally quiet and lightning sferic-free the hours are from just after sunrise to mid-morning, when thunderstorms tend to be at their minimum. Later, the crackling and popping of lightning sferic activity picks up as afternoon thunderstorms build in numbers and intensity. This is due to thermal heating and convection, especially in the summer and autumn months, when, by sunset, the sferics (snap, crackles, and pops) are roaring in a varied and ever-changing texture as lightning storms rage on into the evening. Weather monitoring agencies employ special receivers and direction-finding lightning sferics in order to determine where lightning strikes are occurring and the potential for wildfire ignition, hazards, to aviation, and damage to electric power utilities from those lightning strikes.

While to some, the popping and crackling of lightning sferics may sound like "static," keep in mind that each click or pop is a lightning stroke flashing somewhere, and note just how much lightning is going on even though your local weather may be cloudless. Additionally, distinct seasonal variations in the density of moderate to strong lightning sferics are very noticeable. During the winter months in the mid-latitudes, when the electrical storm density is generally at its lowest, the amount of strong sferics are also at a minimum. Mid-winter, especially in the higher latitudes north of 40°, can be quiet with little lightning sferic activity. However, a weak but continuous background level of lightning sferics may be audible between the few strong sferics—these are from the higher amounts of lightning storms occurring in the tropics and from the opposite hemispheres' summer lightning storms. Contrast that to local summer evenings, when there is a continuous "roar" of lightning sferics heard. The Earth is "awash" with lightning storm activity!

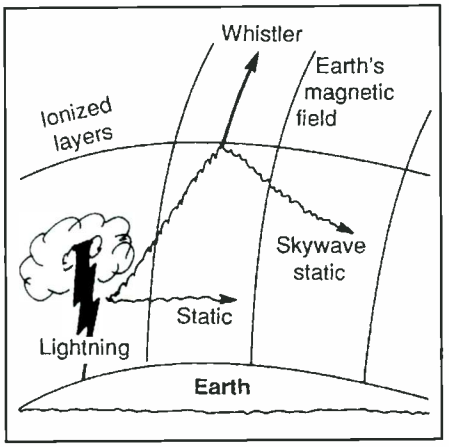
At night, many of the popping and crackling sounds of sferics take on a pinging/dripping sound, called "tweaks," and can be quite musical. Tweaks are a result of the impulse path from the lightning stroke to the receiver being influenced by the Earth surface-to-ionosphere (D and E layers) region, which is about 45 to 75 miles in height, measured vertically during the nighttime hours. This region between the lower ionosphere and surface of the Earth acts as a "duct" or "wave guide" at these VLF radio frequencies, which have wavelengths ranging from 10 miles/29 km. at 10 kHz to over 186 miles/289 km. at 1 kHz, allowing lightning stroke impulse energy to travel considerably farther than during the daytime. As the energy travels and is reflected within this Earth-ionosphere wave guide, the energy undergoes a "dispersion" effect whereby the higher frequencies of the lightning impulse arrive before the lower ones within a fraction of a second. The wave guide dispersion effect abruptly cuts off below about 1.5 to 2 kHz (1,500 to 2,000 Hz) in frequency, resulting in the ringing/pinging "tweak" sound which is also centered around 1.5 to 2 kHz. This "tweak" sound is the lowest resonance frequency of the ionosphere-Earth surface wave guide. This is similar to what sound waves experience in a pipeline.

If you have your hands inside a pipeline between one to three feet in diameter, you will notice a sound similar to the radio sound of tweaks. Because the Earth surface to ionosphere wave guide cannot support radio energy below about 1.5 kHz, the dispersion effect is cut off below the frequency, creating the resonance-like pinging and ringing sound.

The sounds of tweaks can change on an hourly basis from night to night, with the ringing and pinging effect intense and musical at times, especially at night in summer and autumn when there is a higher density of relatively strong sferics. Only a few pops and crackles of sferics may be "tweaking," or all of them can be, and the tweaks may sound "crusty" or be very clean pings and rings. Tweaks can be indicators of the condition and height of the lower layers of the ionosphere to researchers.

In addition to the sounds of lightning sferics and tweaks, you may be hearing downward falling musical notes ranging from nearly pure to "swishy" or "breathy" sounding tones from 1/2- to over four seconds in duration. These are "whistlers," which sometimes happen a couple of seconds after the static crashes and pops of sferics from lightning strokes. Whistlers generally sweep downward in frequency from about 6 kHz to around 0.5 kHz, but the lower cut off frequency does vary remarkably as conditions change, and the upper frequency of whistlers can start higher than 10 kHz. Whistlers sounds quite fascinating. Like "science fiction" sound effects, they are one of the more common Natural Radio sounds you can hear.

The Earth's magnetic field (the magnetosphere) envelops the planet in an elongated doughnut shape with its "hole" at the north and south magnetic poles. The magnetosphere is compressed on the side facing the Sun and trails into a comet-like "tail" on the side away from the Sun because of the "Solar Wind," which consists of energy and particles (plasma) emitted from the Sun and "blown" toward Earth and the other planets via the Solar Wind. Among the charged solar particles caught in the magnetosphere are ions (electronically charged particles), which collect and align along the magnetic field "lines" stretching between the north and south magnetic poles.



The path of a whistler follows our planet's magnetic field as it loops out of our atmosphere, then returns to the surface at a distant point.

These magnetic-field aligned ions bombarding Earth's magnetosphere form "ducts" which can channel lightning-stroke electromagnetic impulse energy. Whistlers sound the way they do because the higher frequencies of the lightning-stroke trade energy travel faster in the duct and arrive before the lower frequencies in a process researchers call "dispersion." A person listening with a VLF receiver in the opposite hemisphere to the lightning-stroke (at the far end of the magnetospheric duct path) will hear this "one-hop" falling note whistler. One-hop whistlers are about 1/3 of a second in duration.

If the energy of the initial one-hop whistler gets reflected back into the magneto-ionic duct to return near the point of the originating lightning impulse, a listener there with a VLF receiver will hear a "pop" from the lightning-stroke impulse, then roughly on to two seconds later, the falling note sound of a whistler, now called a two-hop whistler. Two-hop whistlers are about one to four seconds in duration depending on the distance the whistler energy has traveled within the magnetosphere. One-hop whistlers are usually higher pitched than two-hop whistlers.

The energy of the originating lightning stroke may make several "hops" back and forth between the northern and southern hemispheres during its travel along the Earth's magnetic field lines-of-force. Researchers have observed that the magnetosphere seems to amplify and sustain the initial lightning impulse energy, enabling "multi-hop" whistlers to occur, creating long "echo-trains" in the receiver output which sound spectacular! Each echo is proportionally longer and slower in its downward seeping pitch and is also progressively weaker. Conditions in the magnetosphere must be favorable for multi-hop whistler

echoes to be heard. Using special receiving equipment and spectrographs, researchers have documented over 100 echoes from particularly strong whistlers—imagine how much distance the energy from the 100th echo has traveled—certainly millions of miles/Km! Generally, only one to two echoes are heard if they are occurring, but under exceptional conditions, several echoes will blend into a collage of slowly descending notes and can merge into coherent tones on a single frequency quite unlike any sounds heard outside of a science-fiction movie!

It should be reiterated that strong two-hops (and echoes) can occur from lightning that is within a couple of hundred miles from the listener location, but perhaps from lightning over 100 miles distant. You may notice that "louder" sferics (i.e. closer lightning strokes) often do not trigger the loudest whistlers, of they so at all, but then a loud whistler may come howling through from a relatively weak sferic from quite distant lightning. This is because the lightning impulse sferic energy may propagate within the earth-ionosphere region for considerable distance before entering a magnetospheric "duct." A majority of whistlers are heard ULC during periods of locally fair weather. In fact, Many extremely loud "big whistlers" are heard without any preceding lightning sferic audible whatsoever, indicating the initiating lightning strokes of those strong whistlers are far away—possibly over 3000 miles!

Whistlers are best heard in 30° and 55° north latitude in North America, the prime latitude being 40° and 50° north.

Magnetic Storms, Aurora, and the Beautiful "Chorus"

Occasionally, shortly after sunrise and even extending into the mid-morning, a phenomenon called "Dawn Chorus" may occur. Dawn chorus can resemble the sound of a flock of birds singing and squawking, dogs barking, or sound like whistlers raining down by the hundreds-per-minute (called a "whistler storm"). Dawn Chorus results from hundreds of overlapping, rapidly upward rising tones that can be continuous or appear in bursts, called chorus trains. Chorus trains sound fascinating—the bursts of chirps and squawks (risers) seem to suddenly commence, and over the course of two to five seconds, weaken and fade away, then repeat over again, often in different pitches. During a chorus train, the sounds sometimes seem to be echoing or reverberating back and forth until fewer risers happen, then there may be a brief pause before the next chorus train commences. Chorus trains seem to be harmonically related—a chorus train's center audio frequency may alternate randomly, first centered on about 1 kHz, then another chorus train will suddenly start up one octave higher at around 2 kHz, or maybe 4 kHz. Bursts of chorus trains happening at different octaves can overlap in a beautiful cacophony.

Dawn chorus occurred several times a month during years of high sunspot activity (1989-1993) after solar flares and/or coronal mass ejections on the Sun send a barrage of charged particles into the Earth's magnetic field, causing a geo-magnetic storm and also producing Aurora (the Northern and Southern Lights). In years of low-sunspot counts and few solar flares (1994-1997), coronal mass ejections from the Sun can still cause magnetic storms once or twice a month.

Chorus doesn't always only occur at dawn, especially for listeners located at higher latitudes, particularly in southern and central Canada (50 to 55° north latitude), Alaska, and in northern Europe. This auroral zone is source to a vast amount of natural VLF phenomena. When a solar disturbance on the Sun (such as the solar flare or coronal hole mass ejection) sends highly charged and high-speed particles and ions towards Earth via the Solar Wind, Auroral displays often occur, and are visible to people near the auroral zone oval. Earth's magnetic field also undergoes a "storming" process as well, called a "magnetic storm." During auroral displays, chorus is often heard, as well as "hiss" of various pitches, "sliding-tone emission" which eerily and weirdly rise in pitch slowly over one to several seconds' duration. The chorus which occurs during displays of Aurora is called "Auroral Chorus."

Both Auroral chorus and dawn chorus are related in that they occur during magnetic storms. The more severe the magnetic storm, the farther south away from the auroral zone and the louder the chorus will be heard. The Auroral Zone "oval" surrounding the magnetic poles expands during magnetic storms and reaches farther southward (and the southern Auroral Zone "oval" in the southern hemisphere expands farther northward). Aurora is a daytime phenomenon, but it is not visible to the naked eye due to daylight illumination of the sky. Particularly intense events of nighttime and dawn chorus can get loud even for listeners below 40° north latitude (in the U.S.), and point to the evidence that aurora can reach southward into the middle latitudes despite it not being visible.

The maximum intensity region of chorus emissions, like aurora, can spread southward during magnetically disturbed periods. Daytime aurora can be more intense than nighttime aurora, and events of auroral and dawn chorus reveals quite a bit about the nature of aurora.

Even if geo-magnetic conditions seem "quiet" and chorus events seem likely, conditions may still be very good for whistlers to occur. However, determining when whistlers are going to happen is still a rather unpredictable affair.

The time between local midnight and an hour after sunrise is when the greatest amounts of whistlers are heard, although dusk to midnight may reveal substantial whistler activity, and even (though not very often) loud whistlers may be heard a couple of hours before sunset. Over the long term, the period from two hours before sunrise until an hour after sunrise is the optimum time to listen for natural VLF phenomena of all sorts, as the amount of sferics (lightning stroke pops and crackling) are less—natural VLF phenomena are not as "buried" under the sferics as in the evening when lightning storms are more numerous. Also, magnetospheric conditions are optimum around morning twilight time.

Intense whistler events of short duration can occur at any time between just before local sunset through one to two hours after sunrise. A good whistler event that is happening at 10 p.m., or even at sunset may not be occurring later on that night at the usual optimal sunrise period, so don't rule out the evening hours to listen, especially during geo-magnetic storms.

On several mornings a month, one whistler a minute may be heard on average, but as is often the case, whistlers will not be heard at all. Occasionally during a geo-magnetic storm caused by a solar flare, over 100 whistlers a minute or more may be heard—called a "whistler storm!" Whistlers may or may not have echoes may be few and far between but occur loud, or may

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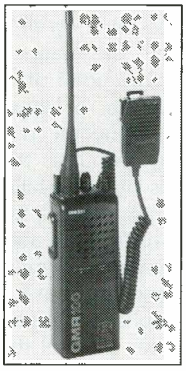

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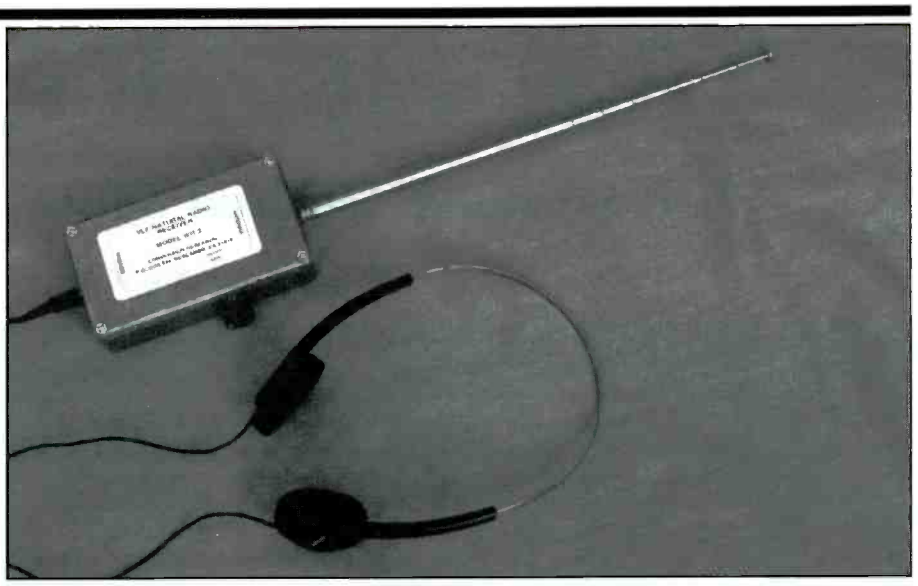
occur often but quite weak. The sound characteristics, intensity, and number of whistlers can change rapidly hour to hour. Everything depends upon the sensitivity and conditions of Earth's magnetosphere and location of lightning storms and magnetospheric ducts in relation to the listener.

Whistlers are seldom heard mid-day, except during unusual conditions occurring with a geo-magnetic storm and when lightning is within a few hundred miles of the listener. Unfortunately, on a good number of days during the year, there will not be any whistlers audible even though there is plenty of lightning activity and sferics within a few hundred miles of the receiver. Often elusive, whistlers may not be heard for days or weeks at a time. Again, it is hard to predict when whistlers are going to occur based on the geo-magnetic indices, but they are generally more common in the spring and fall, surrounding the equinoxes.

Auroral chorus, like whistlers, is best heard between midnight and sunrise. Dawn chorus tends to peak in intensity between sunrise and one hour later.

Listeners to natural VLF radio phenomena shouldn't be discouraged after several listening sessions, whistlers, chorus, or other VLF phenomena sounds are not heard. Soon, you will be rewarded with a myriad of fascinating sounds from whatever VLF phenomena is occurring at the time you listen. Remember, weather and outside temperature permitting, the period around local sunrise will be the most rewarding time to listen. Natural Radio sounds can sound eerie and awe-inspiring, especially when one realizes it is all naturally occurring—not man-made and that these radio emissions have been occurring for millennia. ■



The McGreevy WR-3 is a specialized portable receiver designed for natural VLF phenomena reception.

About the Author: Steve McGreevy is a VLF enthusiast and researcher. He operates S.P. McGreevy Productions, 45 Elda Drive, San Rafael, CA 94903-3723. His company manufactures the popular WR-3 and deluxe WR-3E specialized natural VLF phenomena receivers, also accessories, as well as recordings of VLF phenomena. Check with him for information on these items. His address is S.MCGREEVY@ GENIE.GEIS.COM in the event you communicate by E-mail.

Editor's Note: Readers interested in further exploration of VLF should also consider membership in the Longwave Club of America, 45 Wildflower Road, Levittown, PA 19057. This organization has an excellent monthly publication covering radio activities below 500 kHz, including VLF.

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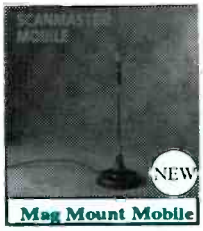

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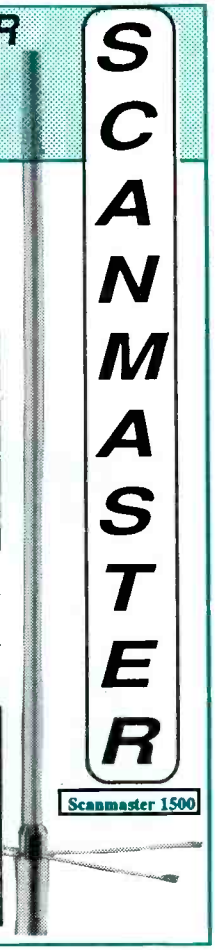

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